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September 20, 2000

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
445 12th St., S.W.
Washington, DC 20554

Re: ***Ex Parte* Notification**
ET Docket No. 98-153
Ultra-Wideband

Dear Ms. Salas:

This is to note that on September 19, 2000, Jeffrey Ross of Time Domain Corporation and Robert Pettit and I of this firm met with Mr. Clint Odom, Legal Advisor to Chairman Kennard, to discuss Time Domain's views on certain issues raised in this proceeding. We provided the enclosed summary of those views. Mr. Ross also supplied some background material on ultra-wideband and Time Domain Corporation. These materials are also enclosed.

Should any questions arise concerning this matter, please contact me.

Respectfully,

David E. Hilliard

David E. Hilliard
Counsel for Time Domain Corporation

cc (with encl.): Clint Odom, Esq.

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Time Domain Corporation
Docket 98-153 Ultrawideband

- The Commission should adopt regulations that allow UWB devices to operate with signal levels up to the Part 15 general limits it has already authorized for billions of digital devices, such as personal computers. TDC is concerned that the Commission is considering regulations that call for a significant reduction in UWB signal strength below 2 GHz. The signals that TDC is proposing to use are at or below the well-established Part 15 limits, and TDC firmly believes that UWB will not cause harmful interference.

- In the NPRM, the Commission suggests that intentional UWB emissions are different from unintentional emissions from digital devices. TDC disagrees. Many digital devices produce waveforms that are very similar to UWB emissions. In fact, many computer designs with microprocessors operating at and above 1 GHz produce pulses with the same duration as many UWB devices. Moreover, to reduce the levels of higher frequency signals now emanating from PCs – in order to meet the Part 15 limits – designers are using techniques that spread the bandwidth of the dispersed energy. Therefore, the interference potential from UWB intentional emitters is consistent with that of digital devices regulated under Part 15 as unintentional emitters and TDC respectfully requests that the Commission carefully consider whether UWB emitters, which by their nature emit wideband signals at very low levels, be held to a higher standard.

- The proposed 12 dB decrease in field strength below 2 GHz – beyond the already incredibly low power levels being proposed – would force TDC and other UWB communications and radar system designers to use a higher frequency signal with different and potentially unsatisfactory propagation characteristics. Filtering UWB signals that operate with a 2 GHz nominal center frequency would drastically alter the key characteristics inherent in UWB signals by altering the signal's pulse shape.

- TDC applauds the Commission's decision to consider allowing UWB emissions below 2 GHz should the interference test results demonstrate compatible operation. The Commission should follow closely the publicly announced testing efforts and provide its comments before completion of the testing in order to increase the likelihood of useful test data being provided. ***NTIA has announced that it will also examine emissions from incidental and unintentional radiators. The Commission staff should observe these tests.***

- TDC agrees with the FCC Technology Advisory Council, Spectrum Management Focus Group, that the noise floor of a receiver will be set by the closest UWB transmitter only, and observes the critical need to account for real-world UWB operational scenarios, which include the operational duty cycle, on/off time duty cycle, propagation losses, victim receiver antenna gain and pattern, ambient noise, and UWB antenna polarization.

September 19, 2000

REACTION-TO-THE FCC'S UNANIMOUS ADOPTION OF A NOTICE OF PROPOSED RULEMAKING FOR ULTRA WIDEBAND (UWB)

"Ultra-wideband is a promising, spectrum efficient [wireless] technology that could provide tremendous benefits for public safety and for persons seeking broadband Internet access,"
-FCC Chairman William Kennard, May 10, 2000

"In a potentially important milestone for a new kind of wireless technology, the Federal Communications Commission unanimously backed a proposal to consider ultra-wideband for operation on an unlicensed basis."
-USA Today, May 11, 2000

"While virtually unheard of by the average person, ultra-wideband is considered by those who know about it to be the answer to just about every communications technology issue today."
-UPSIDE Today, May 16, 2000

"The FCC said the technology, developed by Huntsville, Ala.-based Time Domain Corp., could permit scarce spectrum resources to be used more efficiently by allowing use of spectrum already occupied by radio services without causing interference."
-Dow Jones Business News, May 10, 2000

"UWB has the potential to provide short-range, high-speed wireless data transmissions that could make access to Web pages over the air as fast as a wired connection would be."
-COMPUTERWOLRD, May 15, 2000

"...could help police, fire, and rescue personnel coordinate efforts, as well as locate criminal suspects in hiding or disaster victims trapped in burning buildings or buried in rubble."
-BNA Daily Report for Executives, May 12, 2000

"This appears to be a truly unique technology...promises important new products limited only by the imagination."
-Stan Bruederle, Chief Analyst, Dataquest, May 11, 2000

"This is an important decision for technology, the industry, and for consumers as a whole. We are pleased that the FCC is moving forward on allowing this technology to enter the commercial market."
-Computer and Communications Industry Association (CCIA), May 11, 2000

"Technically, it works--it makes sense.
This could be the next big thing,"
Iain Gillott, vice president, IDC
May 18, 2000

"It holds the promise of dramatically reducing the pressure on the wireless spectrum that carries mobile phone voice conversations and, increasingly, data transmissions."
-CNET News.com, May 11, 2000

"What is unique about ultra-wideband is that the technology has the potential to alleviate several wireless industry problems at the same time, not the least of which is the crowding of the electromagnetic spectrum."
-UPSIDE Today, May 16, 2000

"Just when you thought wireless technology couldn't get any more bleeding-edge, the Federal Communications Commission has lowered a major regulatory hurdle for yet another wireless technology to make a play for the airwaves. Supporters of ultra-wideband wireless (www.uwb.org) say it could be used for all sorts of amazing new applications."
-PC World, May 18, 2000

"The PulsON chipset can be incorporated into a wide range of new products that can improve safety, enhance security and increase spectrum efficiency."
-RCR, May 12, 2000

"Not only might it (UWB) counter the much-maligned wireless spectrum drought, but it also may fuel 3G e-commerce."
-High Yield Report, May 1, 2000

"The technology has the potential to support an array of new uses from radar imaging of objects buried in the ground or behind walls to high-speed data transfer over short distances."
-Reuters News Service, May 10, 2000

"Moving the operation of some commercial services to unlicensed spectrum via ultra-wideband technologies would free up spectrum for more advanced mobile telecom offerings."
-CT Wireless, May 10, 2000

"If this ultra-wideband turns out to be all it's cracked up up to be, it's definitely going to be welcomed in the industry,"
Ken Woo, director corporate communications, AT&T Wireless Group
-UPSIDE Today, May 16, 2000

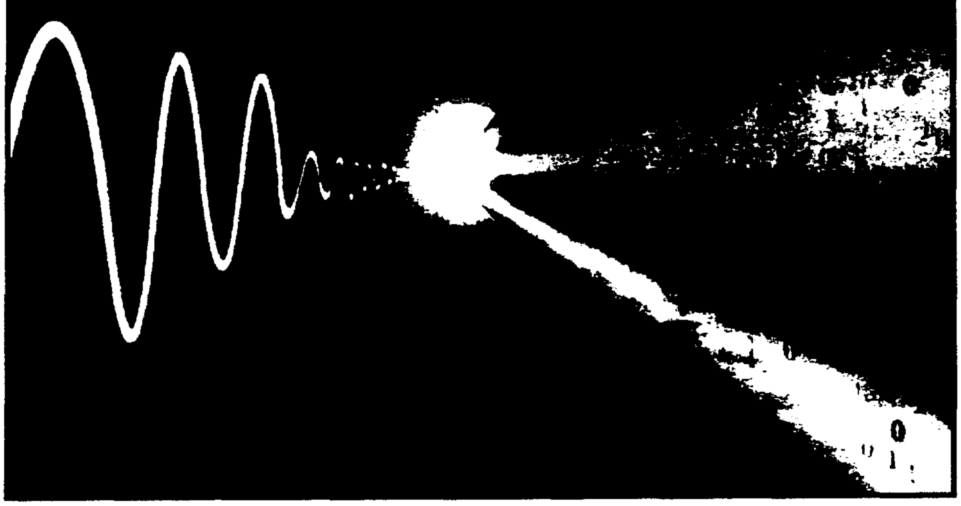
THE NATION'S NEWSPAPER
USA TODAY
NO. 1 IN THE USA... FIRST IN DAILY READERS

USA TODAY
Money

FRI./SAT./SUN., April 9-11, 1999 1B & 2B

Pulsing with promise

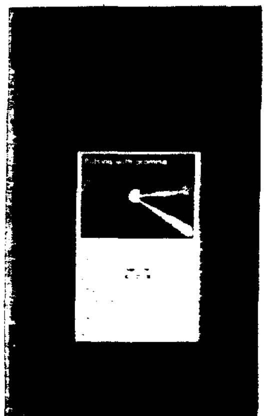
New digital technology likely to revolutionize how we live



By Jim Sergent, USA TODAY

By Kevin Maney
USA TODAY

HUNTSVILLE, Ala.—A little-known company in this city of rocket scientists is about to explode onto the scene with an invention that might be as important as the transistor or electric light bulb.



Front Page Story

COVER STORY

The company is Time Domain. Its breakthrough is the work of Larry Fullerton, a lone inventor who harks back to the era of Thomas Edison. His invention is a way to transmit information wirelessly, but not using radio waves. Instead, it uses pulses of radio energy, fired out at 10 million to 40 million pulses a second.

The potential impact is astounding. If the technology lives up to its promise, it would be like the leap from vacuum tubes to the transistor or from oil lamps to light bulbs, touching every home and workplace. Wireless communicators could get down to the size of a quarter. Radar could become cheap and commonplace. A home radar system could be used for security, detecting movement inside and distinguishing a cat from a man. Already a reality is hand-held radar that police can use to see inside a room before bursting in.

The pulse technology, sometimes also called ultra-wide band (UWB), could launch whole new industries and reorder several existing ones in coming decades.

"This is a technology that's as radical as anything that's come up in recent years," says Paul Turner, a partner at PricewaterhouseCoopers who has studied Time Domain and advised the upstart company. Others agree. Representatives from major technology companies have trooped to Huntsville the past few months. "If they can really pull it off in volume, it can be quite huge," says IBM Vice President Ron Soicher, who admits to getting goose bumps when he realized the potential.

The technology is digital. Each of the whizzing pulses is a 1 or 0, so the transmissions are as flexible as a computer, able to handle phone calls, data or video. The pulses can carry information or media as fast as the speediest corporate Internet connection. The pulse technology has other advantages:

▶ It could open up capacity for radio communication. Today, there's a wireless traffic jam. Users of radio waves have to operate in their specific, government-granted slices of the increasingly crowded radio spectrum; otherwise, they'd interfere with one another. But it's unlikely the pulses would interfere with each other or with conventional radio waves, so the pulses would open up vast new radio real estate.

▶ Pulse devices could operate on one-thousandth the power of devices that use radio waves, so a phone could be the size of a wrist-watch.

▶ The pulses in Time Domain's technology are read by timing the incoming pulses

A BREAKTHROUGH TECHNOLOGY

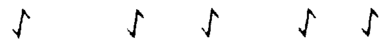
How pulse technology works

Time Domain founder Larry Fullerton has come up with a new way to send and receive signals over the air. For the past 100 years the only way to wirelessly transmit signals— voice, music, TV, data— has been by radio waves.

Waves

Fullerton's digital pulse technology transmits pulses of energy instead of waves. Each pulse represents a 1 or a 0, the digital language of computers. Ten million to 40 million pulses are sent per second, fast enough to carry voices. Web pages and video.

Pulses



The benefits

1 Pulses work around crowded radio spectrum.

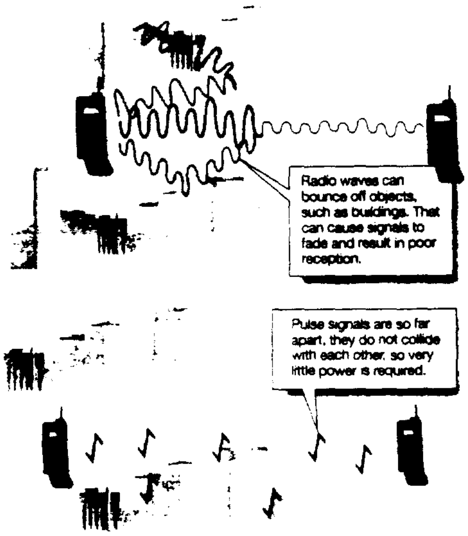
There are limits on how much information waves can carry and how much space there is on the radio spectrum. As things like cell phones and satellites proliferate, the radio spectrum is becoming scarce.

The pulses have no frequency – no slot on the radio dial. Instead, the pulses are spread across the radio spectrum.

Because pulse technology doesn't eat up spectrum, it could unlock the current radio-spectrum traffic jam.

The downside is that in doing so, it might threaten the entities that have spent billions of dollars to buy rights to chunks of radio spectrum.

3 Less battery and transmitter power is needed



The new phone

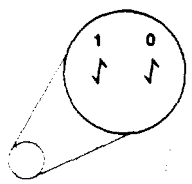
A cell phone built with Time Domain's technology would have three pieces: a transmitter, a correlating receiver and a processor. Eventually, each would be on a single computer chip. They'd all have to work together to make the phone work. What each piece does:

Transmitter:
Sends 10 million to 40 million pulses per second. The intervals are staggered in any of 30,000 different spots within every 100 feet. The intervals vary according to a code stored in the device. The transmitter operates on the same digital principle as a computer, creating all information out of 1's and 0's.

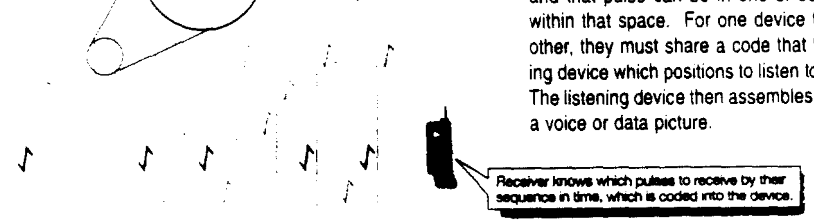
Correlating receiver:
Once the correlating receiver knows the code that governs the intervals of the pulses, it listens at those intervals and figures out whether each pulse is a 1 or 0.

Processor:
The processor acts like a traditional computer chip. It assembles the 1's and 0's into information, then turns it into sound, video, or data on a screen.

2 How the pulses communicate



If a pulse goes out 125 picoseconds earlier than the exact spot prescribed by the code, then it's a 1. If it goes out 125 picoseconds later, it's a 0.



If one device sends out a signal, how does another find and listen to it? The pulses (each 6 inches long) leave a device at precise intervals in time, measured to within 10 trillionths of a second, or 10 picoseconds. There is one pulse for every 100 feet, and that pulse can be in one of 30,000 positions within that space. For one device to listen to another, they must share a code that tells the listening device which positions to listen to in what order. The listening device then assembles the pulses into a voice or data picture.

This timed pulse system has a number of amazing characteristics.

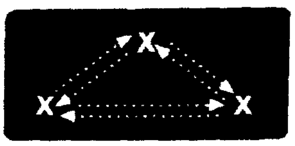
One is security. Because of the astounding number of possible combinations of positions, Time Domain says, there is no way to tap into this kind of communication unless you have the code.

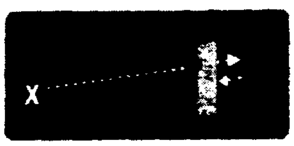
Another by-product of the huge number of combinations is that 2,000 to 20,000 people could use pulsed cell phones in the same square block and probably never interfere with one another or overload the cellular system. A conventional cell phone system can only handle about 400 users in one small area.

Other uses of the technology

Geographic positioning: Because of the precise timing of outgoing and incoming pulses, a device can measure the time it takes for a pulse to get to it or bounce back from it. In doing so, the device can tell how far away the sender of a pulse is or how far away an object is. The accuracy is within less than an inch, compared with 5 feet for global positioning satellite, or GPS, systems. That accuracy could enable farmers to use robotic equipment.

Radar: Using the same technique, the device can act like radar. But unlike radio-based radar, which gets confused indoors because of waves bouncing around, pulsed radar works indoors, through walls and underground. Because pulsed radar requires little power, pocket radar is possible.





By J.L. Albert, USA TODAY

TV, radio, telecom changes in store?

to 10 picoseconds—10 trillionths of a second. Any pulse device could tell how long it takes for a signal to get to it, which makes it able to sense objects and measure their position more accurately than conventional radar. Radar could be a mass-market product for homes or cars.

▶ The pulses are timed according to a complex code shared only by the sender and the intended receiver. The chance of anyone who doesn't have the code intercepting the signal is near zero. That means pulse communications should be the most secure way ever to transmit wirelessly– of major interest to the military.

Fullerton started working on the technology in 1976 and got his first patent for it in 1987. But the technology was crude, Fullerton didn't have the money to push it, and the world wasn't paying attention. All that is changing in a big way.

Photo by Charles Seifried

Pulse wave of the future: Ralph Petroff, left, and Larry Fullerton of Time Domain are working on digital pulse technology.

Band of believers grows

In Time Domain's offices are prototypes of a wireless phone that can measure the distance to the other party, cameras that can transmit video wirelessly to a computer screen, and radar that works indoors and through walls, which conventional radar can't do. The prototypes are hand-built and clunky. "We haven't built a lot of things yet, so we don't know how much reality will intrude on theory," CEO Ralph Petroff says. "But our guys say they can do it."

The list of believers is growing. The Federal Emergency Management Agency has contacted Time Domain because its radar technology could pinpoint victims beneath an earthquake's rubble. "This technology has the potential to reduce casualties among civilians and rescue workers alike," says a comment FEMA filed with the Federal Communications Commission.

The Marines have been looking at Time Domain prototypes because they'd like a walkie-talkie that's not only undetectable but can tell a Marine the location of all the other members of his unit. The Immigration and Naturalization Service is doing a pilot project with Time Domain. It's interested in ways the technology could be used along the border. Put a wireless, low-power camera in a cactus, and it could transmit video back to INS agents; no need to string telltale wires across the desert.

A few pulse technology products are ready for a broader market, pending FCC approval. Time Domain has made handheld radar that police could use to see inside a room before bursting in. A couple of small companies are making pulse radar devices for measuring liquid in steel storage tanks. A handful of research labs, such as the UltRa Lab at the University of Southern California, are experimenting with pulses.

Mass-market products are still years away. Cell phones, Petroff predicts, are a decade off. "There are still three to four iterations of design that have to go on before we really know if it all looks good," says Robert Scholtz of UltRa Lab. "Still, no one has disproved its potential."

Recent developments are giving the technology a head of steam.

Until about a year ago, Fullerton's invention was, as he says, "a science project." It worked only in theory or in awkward and costly lab experiments. Then IBM came up with a new way to make a chip using the material silicon germanium. That chip turned out to be perfect for measuring time to the picosecond and controlling release of the pulses—at low cost. Working with IBM's Soicher, Time Domain became a test project for the chip. "It's been a perfect match," says Alan Petroff, brother of Ralph and head of Time Domain's engineering work. "We wouldn't be doing this now if not for that."

Another development has to do with money, and lots of it. In 1995, Time Domain was an 11-person Huntsville company that struggled to make payroll. Since then, the Petroff family, which previously had built a multinational environmental engineering company, invested $3 million and took over management. (Fullerton, who admits he's an inventor, not a manager, still owns more than 20% of Time Domain and is the company's most valuable asset.) The Petroffs have raised an additional $17 million from dozens of investors, many from Silicon Valley.

The money has enabled Time Domain to build prototypes, hire engineers, do some marketing and get to critical mass. "They now have a backbone of credibility," says Heidi Roizen, a powerful Silicon Valley player who has advised Time Domain and introduced it to the computer and Internet crowd. "They have proved their concept, and they've gotten out to meetings" and people are taking them seriously, she says.

New industries, not old

Events this week are helping. Today, the House Science Committee is releasing a report that could clear up confusion about the technology. For most of the 1990s, Fullerton has been in a patent dispute with the federal Lawrence Livermore

National Laboratory. He alleges that Livermore tried to swipe his pulse technology by applying for a similar patent in 1993. In a preliminary ruling, the Patent Office has thrown out Livermore's key patent claims, citing Fullerton as the true inventor. In today's report, the House Science Committee will castigate Livermore for its behavior and say Fullerton is the inventor.

Tuesday, Ralph Petroff gave a brief report to FCC commissioners at their invitation. It was a sign that another obstacle might begin to move. No one can even test a pulse-transmitting product without approval from the FCC, and so far, the FCC has granted none. In fact, the agency has been very wary of the technology, which doesn't fit with anything it has experienced before.

The technology has come far enough to let Time Domain and others begin thinking of ways Fullerton's invention could change the world.

Certainly the technology could have a profound—maybe devastating—effect on several existing industries. Companies in TV, radio and telecommunications have spent billions of dollars buying rights to slots on the radio spectrum and billions more developing products to use on those slots. It might take decades, but Time Domain's technology could make those rights far less valuable and the products obsolete. "This is really a paradigm buster," says Bennett Kobb, author of *SpectrumGuide*, which keeps tabs on radio spectrum.

Time Domain, however, pointedly says it's not trying to go at existing industries head-on. For one, it would rather have companies like Motorola and AT&T as allies, not enemies. "Time Domain has to try to get into the market in a manner that's as nonthreatening as possible to other stakeholders, who will try to protect their turf from any kind of alien thinking," Kobb says.

Second, Ralph Petroff says he's interested in spawning new industries, not scrambling old ones. Time Domain wants to use the Intel business model. It would make the internal chip set that could power any product: Time Domain inside. Entrepreneurs and big companies would come up with the innovative products based on the technology. Just as no one could imagine how the transistor would be used when William Shockley fathered its invention in 1947, no one knows how pulse technology might be used.

But Petroff has some intriguing ideas. For instance, the technology's ability to measure a position is so good, it can be accurate to within less than an inch. That would allow for what Petroff calls precision farming. Put pulse technology on a tractor, and the vehicle could plow a field by itself. Or the positioning aspects might allow for the creation of a self-guided bricklaying machine.

Time Domain technology could be perfect for the blossoming industry of home computer networking. The single biggest obstacle to home networking is the wiring: Who wants to string another set of wires to every computer, printer, TV and other device around the house? With pulse technology, you might be able to put a box on the side of the house that would be powerful enough to transmit TV, the Internet and phone calls to any device inside.

Tinkerer solves puzzle

The credit for all this rests with Fullerton. Inventors like him seemed to have died with the complexity of the modern age: one person, tinkering in a private lab, creating something entirely new.

"He is a brilliant inventor, and he does have a lot of the sort of Edisonian quality," says Turner of PricewaterhouseCoopers.

Fullerton is 48, married, with two grown children. He's had a lab since he was 7. His father was in the military, and they moved a lot. His labs went with family. At 13, he was introduced to amateur radio by a neighbor at McChord Air Force Base in Tacoma, Wash., and was fascinated. He went to the University of Arkansas in Fayetteville, Ark., where a favorite professor, Leonard Forbes, told the class one day of a theory of pulsed communication. Research on the theory had been going on for years. But, Forbes said, pulses could never be transmitted.

"I couldn't think of a reason it wouldn't work," Fullerton says. And if it worked, he realized, its potential would be awesome.

He kept experimenting in his home lab until one day he used pulses to transmit music—a tape of the album *Chicago* III from his workbench to a hand-held receiver in his yard. "When it worked, I got kind of a spooky feeling," he says.

He got jobs with big companies—Texas Instruments, ITT, CSC—and started a small, not-very-successful one. He kept tinkering. CSC brought him to Huntsville, where he looked up a patent attorney and won his first patent. He now has 10 U.S. patents for pulse technology and 32 abroad.

Lanky and bearded, Fullerton comes across as painfully shy, but underneath he is steely and wily. He met Alan Petroff in the 1980s. Peter Petroff had come from Bulgaria to work with Huntsville's rocket scientists building the U.S. space program in the 1960s. He then invented the digital watch, founding Pulsar in 1969, and later built ADS Environmental Services with his three sons, Ralph, Alan and Mark.

By 1995, Fullerton lured in Alan Petroff, who took a $25,000 salary just to get in. A year later, the rest of the Petroffs joined him. "We had all planned to retire," says Petroff, now 44.

The Petroffs brought money and management. Without them, Fullerton's invention might have died.

Hurdles to history books

Time Domain still faces obstacles aplenty. It needs to build more prototypes to prove without a doubt that the technology works as advertised. So far, the company has encountered no serious glitches in its march to do so. Time Domain also needs to carefully choose partners—staying wary, as Roizen advises, of big companies that might then bury the technology amid bureaucracy and infighting.

The FCC is a huge obstacle. Time Domain has been trying to prove that pulse communications would not interfere with other signals on the radio spectrum, but Scholtz says that's "still an open question." The FCC has not yet granted Time Domain waivers to test products. Commercial products will require a major rule change that can take to two years. But the FCC is listening.

I hope (that it would be approved)," says John Reed of the FCC's technical rules branch. "There are quite a few benefits that could be obtained from it."

And since Time Domain plans on building innards, not products, "it must ignite the entrepreneurial community so people will build these things," Roizen says.

But the technology seems to be on the right path.

"Until a few years ago, I'd wake up in the middle of the night and say, 'What am I doing?'" Fullerton says. "But the way I feel now, there's no stopping it."

Contributing: Peter Eisler

THE YEAR IN PHOTOGRAPHS

U.S.News & WORLD REPORT

JANUARY 3 10, 2000

www.usnews.com

Outlook 2000

DOUBLE ISSUE

A New Age of Innovation

Breaking the Genetic Code

Bold Ideas From Big Thinkers

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U.S. NEWS ONLINE: **www.usnews.com**
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COVER STORY

With their bold ideas and cutting-edge tools, these scientists hope to change the face of the 21st century.

 U.S.News & World Report (ISSN 0041-5537) is published weekly, except for one combined issue mailed in July and a second combined issue mailed in December. $44.75 per year, by U.S.News & World Report Inc., 450 W. 33rd Street, 11th Floor, New York, NY 10001. Periodicals postage paid at New York, NY, and at additional mailing offices. POSTMASTERS: Send address changes to U.S.News & World Report, PO Box 55929, Boulder, CO 80328-5929. *U.S. News* may allow others to use its mailing list. If you do not want your name included, please contact our Subscription Department by mail or phone. U.S.NEWS & WORLD REPORT® U.S. NEWS® WORLD REPORT® NEWS YOU CAN USE® WASHINGTON WHISPERS® Canadian Post International Publications Mail (Canadian Distribution) Sales Agreement No. 545643, Canadian Goods and Service Tax No. R124481334
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Larry Fullerton

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Born: Dec. 11, 1950, Fayetteville, Ark. Education: B.S.E.E., University of Arkansas. Role models: inventors like Edison and Marconi. Proudest accomplishment: winning a gold medal in the high jump in high school. Favorite book: *Atlas Shrugged*. Chief dislike: "Bureaucracy is way up there." Favorite pastime: astronomy. "Galaxies are my favorite."

BY AVERY COMAROW

As a teenage ham radio operator more than 30 years ago, Larry Fullerton would try to squeeze his pipsqueak of a signal into the crowded frequencies assigned to hams. He was routinely muscled aside by beefier transmissions from operators who could afford high-powered equipment. All the boy could do was prowl for vacant spots, slivers of spectrum the bullies had overlooked.

In the decades since, the battle for spectrum space has moved far beyond skirmishes among radio enthusiasts. Most of the radio spectrum has been given away or auctioned off by the Federal Communications Commission. The explosion of pagers, cell phones, and other telecommunications services, as well as advanced government and military systems that use radio waves, has generated intense competition over the remaining scraps.

The Internet is worsening the crunch. By some estimates, tens of billions of computers and other "Internet appliances" will be connected to the Net in five years or so. There won't be enough fiber-optic cable hooked up to carry all that data. If even a small percentage of the new traffic is funneled through satellites and other wireless devices, they will need frequencies from somewhere in the radio spectrum.

And that's where Fullerton, now founder and chief technology officer of Time Domain in Huntsville, Ala., re-enters the picture. The engineer, who came to Huntsville in 1979 to work for NASA but left because he "ran into miles of red tape," has designed a circuit that may ease the squeeze through the use of "ultrawideband" (UWB) technology. The design is etched into high-speed chips that blend silicon and germanium. Fullerton overflows with large and small ideas for chip-based products. One prototype device, called RadarVision, is a portable radar about the size of a ream of typing paper that can see through walls and detect very small movements. That means it could locate people trapped in the rubble of collapsed buildings and earthquakes. A cheap wireless home telecommunications network and a gadget that can find a car lost in a parking lot also are in the works.

Data hiccup. In Fullerton's scheme, digital data are not transmitted on a single frequency or small band of frequencies, as is typical. Rather, information is sent as a pulse half a billionth of a second long across a wide swath of the spectrum already used by global positioning systems, military satellites, and commercial radar (1 to 3 gigahertz).

Fullerton would sidle unnoticed into the throng by transmitting at extremely low power—no more than 50 millionths of a watt, or less than 1/10,000 the punch of a cell phone. Devices equipped with Fullerton's chip could read the data hiccup, but to conventional communications equipment it would be lost in the background noise. Multiple ultrawideband devices could operate in the same room, because the coding of the pulsed information would be unique to each product.

As RadarVision demonstrates, the ultrawideband pulses also penetrate thick layers of concrete as if they were tissue paper. Integrating the chip into cell phones would allow co-workers to talk with each other within a building, which isn't always possible now.

Fullerton has plans for a $30 home network that would link computers, TVs, wireless phones, and other appliances without wires or cables, and an ultrawideband "tag" that would pinpoint a car in a sea of vehicles parked at an airport or stadium. He wants such products to be affordable—$5 to $100. Several should be poised for delivery by next Christmas.

Whether they will be under the tree depends largely on the FCC, which will have to modify its rules to allow ultrawideband transmissions. Fullerton is optimistic, and his brainchild is attracting capital. Siemens, the German telecommunications giant, put $5 million into Time Domain in November. "I'm not so wise as to know where this will take us," says Bjoerne Christensen, president of Siemens's U.S. venture capital group. But it is an idea, he says, "that represents a truly fundamental change." ●

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The Economist

Bandwidth from thin air

Two new ways of transmitting data by wireless exploit unconventional approaches to create valuable additional capacity

They may be invisible, yet chunks of radio spectrum are fought over just as much as parcels of land. Governments raise billions by auctioning parts of the spectrum to mobile-phone companies and radio and television stations. Other frequencies are reserved for air-traffic control or the sending of distress signals. The most desirable addresses on the spectrum, like apartments in the trendiest parts of town, are in short supply—hence the high prices paid for them. To make the most of limited "bandwidth", as it is known, engineers have devised elaborate schemes to allow several devices (such as mobile telephones) to share a single frequency by taking turns to transmit.

Two emerging technologies now promise to propel such trickery into new realms, by throwing conventional ideas about radio transmission out of the window. The first involves multiple simultaneous transmissions on the same frequency. The second, by contrast, transmits on a huge range of frequencies at once. Outlandish though it sounds, the effect in both cases is to create hitherto unforeseen reserves of valuable bandwidth, practically out of thin air.

Don't all talk at once. Actually, do

Turn the dial (or press a button) on a radio, and you determine which station's signal is played through the speaker. Now imagine that several radio stations are transmitting on exactly the same frequency, so that their signals interfere with one another. Is it possible to build a new kind of radio, capable of separating the signals, so that just one of them can be heard clearly?

The conventional answer is no. Once radio signals have been mixed together, trying to separate them is like trying to unscramble an egg. In 1996, however, Gerard Foschini of Bell Labs (the research arm of Lucent Technologies, based in Murray Hill, New Jersey) suggested that multiple transmissions on a single frequency could be separated after all—by using more than one receiving antenna and clever signal processing. The result was a technology called Bell Labs Layered Space-Time, or BLAST.

The prototype system, which is now being tested, transmits via an array of 12 antennae, all of which broadcast a different signal, but on exactly the same frequency. At the receiving end are 16 antennae, also spaced out, each of which receives a slightly different mixture of the 12 broadcast signals—which have bounced and scattered off objects along the way.

Computer analysis of the differences between the signals from the receiving antennae, helped by the fact that those receiving antennae outnumber the transmitting ones, enables the 12 original signals to be pieced together.

Exploiting this result, it should become possible to transmit far more data than before over a wireless channel of a particular size. For convenience, the researchers used a channel "width" of 30kHz, the size of the channel used by analogue mobile phones. Normally, a data-hungry process such as accessing a web page over such a link is painfully slow. But using BLAST, transmission speeds of up to 1m bits per second have been achieved. By increasing the number of antennae at each end, it should become possible to squeeze even more capacity out of a fixed-size channel, albeit at the cost of far greater computational effort.

The technology is not, however, intended for mobile use. The multiple transmitting and receiving antennae, and the powerful signal-processing hardware involved, will be difficult to fit inside portable devices. In any case, too much moving around causes the mixture of signals received by each of the antennae to vary in ways that even the most sophisticated computer cannot cope with. Instead, according to Reinaldo Valenzuela, who is in charge of the research, BLAST is more suitable for use in fixed wireless applications, such as providing high-speed Internet access to homes, schools and offices, or establishing telephone networks in isolated areas without laying cables.

If transmitting several signals on the same frequency sounds odd, what about transmitting on many frequencies simultaneously? That is the principle behind another novel form of wireless-communications technology known as ultra-wideband (UWB). This is being developed by a small company called Time Domain, which is based in Huntsville, Alabama. The technology is the brainchild of Larry Fullerton, an engineer who has spent the past 23 years working on the idea.

Whereas conventional transmitters (and BLAST transmitters) operate at a particular frequency, just as a single key on a piano produces a particular note, a UWB transmitter emits a pulse of radiation that consists of lots of frequencies at once, akin to the cacophony that ensues when all the keys on a piano are pressed at the same time. The pulse is very short—just half a nanosecond (billionth of a second)—and is transmitted at extremely low power. Because it is a mixture of so many frequencies, such a pulse passes unnoticed by conventional receivers, which are listening for one particular frequency.

But to a UWB receiver, listening on a wide range of frequencies at once, it registers as a distinct pulse. Information is sent by transmitting a stream of pulses—apparently at random (to fool conventional receivers), but actually at carefully chosen intervals of between 50 and 150 nanoseconds, in a pattern known to both transmitter and receiver. By varying the exact timing of each pulse to within a tenth of a nanosecond, slightly early and slightly late pulses can be used to encode the zeroes and ones of digital information. The resulting system can transmit data at 10m bits per second, without any interference with conventional transmissions.

Or so Mr Fullerton and his backers at Time Domain contend. So far, however, America's Federal Communications Commission (FCC) has not approved the technology for anything more than experimental use. But there are signs that UWB could, after a long gestation, soon emerge into the marketplace. At a conference in September to rally support for it, Susan Ness, an FCC commissioner, spoke in support of the technology and said regulations permitting it to be used would be announced next year.

Several firms are lining up to make products based on UWB technology. Time Domain, which owns the relevant patents, plans to supply these firms with its chip, called PulsON, to do the hard work of generating and detecting UWB pulses. And as well as communications, UWB also has an intriguing potential use in radar (see article).

Neither BLAST nor UWB quite create something out of nothing. Both technologies cunningly conjure up extra bandwidth at the cost of increased computational complexity. Over the past few years, however, the cost of computing power has plummeted, and demand for bandwidth has soared. Trading one for the other could prove to be a very good deal.

How to look through walls

Besides its use in communications (see other article), ultra wideband (UWB) pulse radio might have a future as a radar that can see through walls, and do so in great detail. It should, its manufacturers hope, be able to distinguish a cat from a cat burglar, or detect barely breathing bodies under several metres of rubble after an earthquake. More mundanely,do-it-yourself enthusiasts will be able to use it to check for power cables and pipes beneath the plaster before they start drilling.

UWB radar works like normal radar in so far as it depends on sending out radio signals and listening for the reflection. But unlike ordinary radar, which takes the form of continuous waves, UWB signals are short pulses of energy.

As a means of radio communication, UWB works because the chips in the receiver are able to time the pulses they are hearing to within a few thousand-billionths of a second. Even at the speed of radio (ie, the speed of light), a pulse will travel only a few millimetres in that time. Since, in the case of radar, the receiver is also the transmitter, it knows exactly when a pulse was sent. By measuring how long that pulse takes to return, it can place the distance to the point of reflection to within that level of accuracy—enough to tell whether an aircraft's wing-flaps are up or down. Four million pulses a second are sent out to provide a near-perfect picture of what the target looks like.

Conventional radar relies on high-frequency (and therefore short wavelength) radio waves to achieve high resolution. Long waves would produce fuzzy images. But when the resolution depends on pulse-length, wavelength does not matter. So UWB radar can employ significantly longer wavelengths, and these can penetrate a wide range of materials, such as brick and stone, which are denied to their shortwave cousins.The result is "RadarVision", which, like the communication technology, is manufactured by Time Domain. Though still experimental, it is being tested by several police forces around America. They are using it to look inside closed rooms that might be harbouring suspects, before the guys with the sledgehammers batter the door down. If it works, television cop-shows will never be the same again.

AS SEEN IN
The New York Times

C1
MONDAY, DECEMBER 21, 1998
Business Day
The Information Industries

F.C.C. Mulls Wider Commercial Use of Radical Radio Technology

By JOHN MARKOFF

The Federal Communications Commission is considering changing its regulations to permit the use of a radical and controversial communications technology that has the potential to make vastly more efficient use of the increasingly precious radio spectrum.

Known variously as ultrawide band radio and digital pulse wireless, the new technology has a broad range of possible applications, from wireless voice and high-speed data communications to land mine detection and advanced radar systems that could permit law officers to see through walls or could aid cars in avoiding collisions.

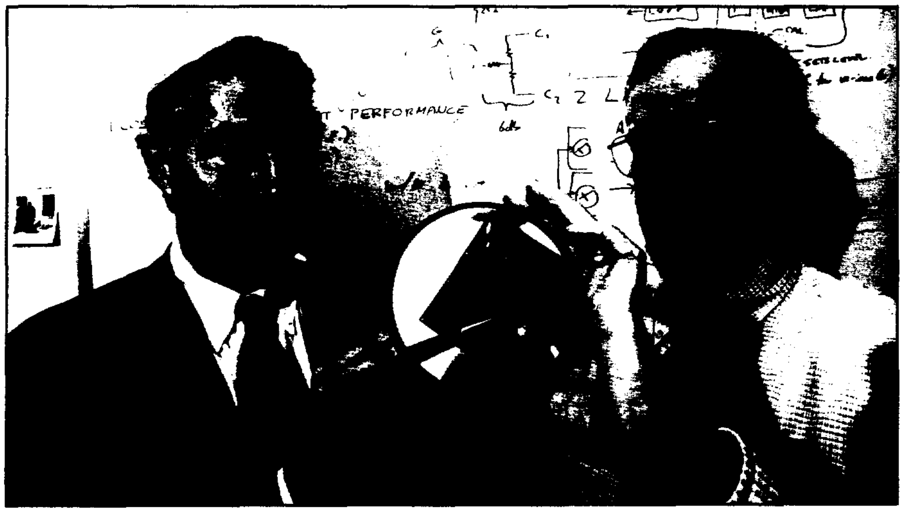
Despite its potential, however, the technology is not in widespread commercial use today because it would run afoul of F.C.C. restrictions that prohibit radio transmissions in certain frequencies set aside for civilian aviation and military agencies.

That could change if the agency agrees to proposals made earlier this month by three small companies that are pursuing the technology for a variety of commercial products.

Unlike communications technologies that send information in analog form, ultrawide band uses a digital transmission consisting of small on-off bursts of energy at extremely low power but over almost the entire radio spectrum.

By precisely timing the pulses within accuracies up to a trillionth of a second, the designers of ultrawide band radio systems are able to create low-power communications systems that are almost impossible to jam, tend to penetrate physical obstacles easily and are almost invulnerable to eavesdropping.

The **Time Domain Corporation**, based in Huntsville, Ala., has petitioned the F.C.C. for a waiver so that by the middle of next year, it can begin selling a system that will permit police officers and special



Ralph Petroff, left, and Larry Fullerton of Time Domain. John Godbey for The New York Times

weapons and tactics teams to see through walls and doors to detect the location of people. The company is also planning a covert communications system that will both carry voice communications and display locations of a counterterrorism or S.W.A.T. team's members.

"We are focusing on the safety systems because it has a great public benefit and it's a good way to introduce the technology where it can make a difference," said Ralph Petroff, the company's chairman and chief executive.

However, Time Domain executives as well as many experts familiar with ultrawide band believe that the technology's real commercial potential lies in extremely lowcost communications applications. That would entail a fundamental shift in F.C.C. regulations, a process that could take years.

"When you take its attributes and compare it to the competition, you have very interesting technology that could lead to awesome possibilities," said Paul A. Turner, executive director of the PricewaterhouseCoopers Global Technology Center in Menlo Park, Calif.

The most promising application for ultrawide band radio might eventually be an alternative to today's wireless office network technologies that are generally able to transmit data at rates between one and three million bits a second.

Because of its design, ultrawide band advocates say, the technology has the potential to deliver vastly higher amounts of data because a large number of transmitters could broadcast simultaneously in close proximity without interfering with one another.

"The most promising applications are not so much as an alternative to cellular telephone," said Lawrence E. Larson, an electrical engineer at the University of California at San Diego. "It may rather provide a much better way of doing short-range data communications because it's very energy efficient."

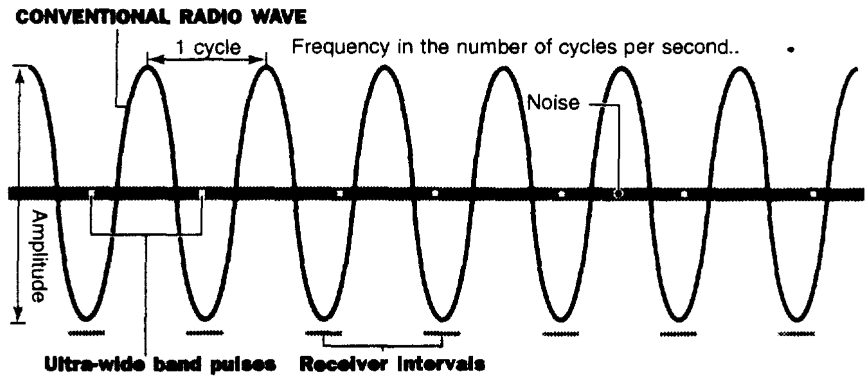
The computer and communications industries have already settled on a standard known as Bluetooth for wireless connectivity in an unlicensed frequency band at 2.4 gigahertz. Bluetooth, which can send a million bits a second about 30 feet using 100 milliwatts (about a tenth of a watt), is intended to interconnect devices like palm computers, laptops and cellular phones.

In contrast, Time Domain's devices can

Communicating Below a Whisper

Several small companies are developing a technology that uses low-power radio signals emitted at regular intervals across a broad range of the radio spectrum for digital communications and radar systems. Here is how the technology works.

The radio spectrum is divided into hundreds of frequencies, each reserved for commercial and military applications. To be detected, these radio waves must have a certain minimum amount of power, called amplitude. While TV antennas, wireless telephones, and many other things generate high-energy radio waves, there are also low-energy waves, called "noise," that come from operating equipment, like computers.



The new technology emits radio signals in pulses across much of the radio spectrum that have no more power than normal background "noise."

Receivers listen for these pulses at regular intervals. Information is conveyed by varying the time between each pulse.

Because the pulses are low-energy, they do not interfere with the normal functioning of radio equipment operating at the same frequency.

The New York Times

currently transmit 1.25 million bits a second up to 230 feet using just 0.5 milliwatts, or one thousandth the power used by Bluetooth. These transmission are being achieved with the first working prototype chips the company has received from **I.B.M.**, which fabricated them using the advanced silicon germanium semiconductor material developed for communications applications.

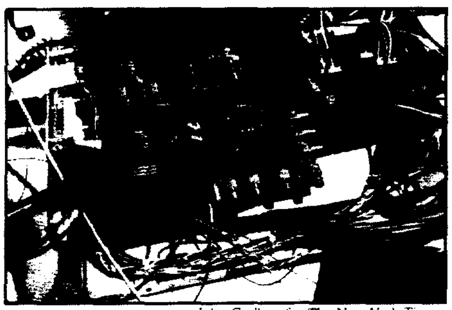
Standard wireless transmissions encode data in a continuous sine wave by varying the amplitude (the size of the wave) or the frequency (the number of times the wave

The ultrawide band system could be used to 'see through' walls.

cycles each second), sometimes both. In contrast, Time Domain's technology is similar to a Morse code system that at this point in its development, switches on and off 40 million times a second. And unlike traditional radio signals, which are confined to a very narrow frequency, each pulse of ultrawide band is transmitted across a wide portion of the radio spectrum, so that only a tiny amount of energy is radiated at any single frequency.

The company said it believed that the bandwidth, or data-carrying capacity, of its technology can be expanded to many times its current limit—perhaps as high as billions of bits a second.

Moreover, while standard narrowband wireless technologies have a limited band-



John Godbey for The New York Times

A silicon chip developed by Time Domain. The chip, which can be used in ultrawide band radio systems, transmits 40 million coded wireless pulses a second.

width, the digital pulse approach has the potential to handle a large number of simultaneous users in close proximity, Time Domain officials said.

Ultrawide band has the added advantage of being significantly more resistant to "multipath interference," a problem that plagues indoor radio systems because signals tend to bounce off many surfaces.

Industry officials said they did not expect an early resolution to the F.C.C.'s inquiry, which was begun in August. One particular obstacle is that a key official at the Federal Aviation Administration has filed an objection with the F.C.C., warning about a potential problem caused by the clustering of large numbers of transmitters, even at very low power levels.

Industry officials note, however, that current F.C.C. rules permit "incidental" emitters—generally, consumer devices like personal computers, hair dryers, electric razors, automobiles and arc welders—and that no hazard has been demonstrated from the hundreds of millions of these products in everyday use.

Last month, a group of scientists and engineers met at the **Interval Research Corporation**, a computer industry research center financed by Paul Allen, a co-founder of the Microsoft Corporation, to coordinate industry input into the F.C.C. decision-making process.

More recently, an Interval physicist, Roberto Aiello, filed an independent comment with the agency, reporting that a simulation by his research group indicated that even if millions of ultrawide band transmitters were allowed to operate, they would have a negligible impact on aviation and other communications systems.

"The F.A.A. is worried about this, and I think it's a good position for them to take," Mr. Aiello said. "But I think there's concrete evidence that there will not be interference from ultrawide band."

In addition to Time Domain, companies asking the F.C.C. for exemptions from spectrum rules include Radar Inc., which is developing a system for finding buried objects and looking behind walls, and the **Zircon Corporation**, a maker of devices for such tasks as finding joists in wails.

HERRING

LATEST NEWS March 17, 1999

CATCHOFTHEDAY

Wireless's Twilight Zone

ATLANTA, GEORGIA –
At the Venture Market South conference on Tuesday, I sat in on Time Domain's presentation by CEO Ralph Petroff. He had a video that pitched the "new dimension" in wireless data. It took me back to last year's Venture Market East conference in Boston, at which the CEO of Nexabit, Mukesh Chatter, talked about building routers "about 100 times faster than anything Cisco has on the market." Since then, the terabit router market has begun to open up, and I have to credit visionaries like Mr. Chatter who are unwilling to accept that a market must move at the incumbent's pace.

Time Domain, potentially, has even more disruptive technology. Its "time-modulated ultra-broadband wireless" chip enables ultra-fast, ultra-low-power radio transmission. It uses what's considered the "noise" of ordinary frequency bands, so it doesn't even need traditional spectrum allocation. On paper, it smokes the Bluetooth standard. Time Domain has already raised $26 million, and judging by the poker faces on the venture funders who met with Mr. Petroff after his presentation, there's plenty more cash eager to get behind this company. Watch this one.

-Rafe Needleman, Editor

News Analysis

ULTRAWIDEBAND: GOLD IN THE "GARBAGE FREQUENCY"

New devices that use low-level emissions can improve your golf game—or find survivors in collapsed buildings, if the FCC approves

Everyone is talking about broadband wireless these days, but few people have heard of a new technology with thousands of potential applications: ultrawideband. That's probably because it's not legal yet. But that's not stopping three new companies from finding their own niche in the as yet non-existent market.

Time Domain Inc., US Radar Inc., and Zircon Corp. were all granted exclusive waivers by the Federal Communications Commission earlier this year to begin marketing their version of ultrawideband technology on a limited basis to test its safety and effects. Provided the government approves ultrawideband this year — a likely prospect — these companies, which the FCC chose based on their distinctive and nonoverlapping markets, will soon offer products using signals, or pulses, that don't fit into any one part of the spectrum. That will give them access to unlicensed, free air space.

Here's how it works: Everything from microwave ovens and cell phones to the human body emits very low levels of radiation. Generally, these low-level emissions fall into what's called the "garbage frequency" part of the spectrum, also known as Part 15 of the FCC licensing code. It's illegal for a company to create a product that intentionally uses these frequencies, because these random emissions contribute to what is called the "noise floor" — the cacophony of signals currently bouncing around the airwaves. If enough signals are concentrated in one area — i.e., a high noise floor — they can wreak havoc with wireless devices. That's why some apartment dwellers have a hard time getting good cordless-phone or radio reception, and why airlines prohibit use of cell phones during takeoff and landing.

MINE SWEEPER. With careful regulation of the junk spectrum, however, plenty is available for everyone (see BW Online, 3/16/00, "Commentary: Wireless Demand Creates a Whole Spectrum of Problems"). At a recent FCC conference in Washington, D.C., proponents of ultrawideband technology defended its use against aviation groups concerned that it will interfere with the Global Positioning System used to navigate airplanes. The general consensus was that more testing needs to be done before these new products are released on the market.

But in the meantime, the FCC is confident enough that it has already started the paperwork necessary to approve the technology by yearend. And an Ultrawideband Working Group has been formed, consisting of 80 companies pledging to work together to ensure the safety of the technology.

That's good news for Time Domain, US Radar, and Zircon. Each company is planning to concentrate on specific products in potentially lucrative markets: Time Domain's spin-off Golf Domain.com will provide low-cost pulse radar on golf courses. US Radar is concentrating on surface-penetrating pulse radar to locate land mines and artifacts. And Zircon is perfecting a high-tech stud finder for use by concrete and highway contractors.

By Susan Straight in Washington

SUPERCADDIE. Golf Domain.com has a Web site that will go up in April. The product: tiny electronic "caddies," about the size of a pager, that can be attached to trees, telephone polls, sheds, or just about anything else on a golf course. With the aid of another electronic caddy that attaches to the belt, golfers can locate lost balls, tell the distance of a ball from the hole, judge the type of club to be used, measure the distance to any hazards on the golf hole, and get a reminder of the score they got on the same hole the last time they played. These solar-powered caddies do all this by emitting a series of precisely timed pulses in a specific pattern patented by Time Domain.

Golfers would also find a bonus waiting on the 19th hole: A wireless Internet connection back to the clubhouse providing players with a 3-D image of their ball's trajectory on any given hole. Future applications include 3-D images of your swing, plus enhanced TV viewing of golf tournaments. The PGA Tour has already expressed interest, according to Dale Crook, CEO of Golf Domain.com. While initial setup fees would be substantial — $30,000 to wire an 18-hole course — that's far cheaper than any other existing positioning technology. And Crook boasts that it could eventually be tooled to control electronically controlled lawnmowers to trim fairways.

Matawan (N.J.)-based US Radar is perfecting surface-penetrating radar (SPR), a technology it first developed in 1982 to find land mines on the Falkland Islands after the brief war between Argentina and Britain. Besides being better at detecting the plastic used in modern land mines, the device is far more precise and versatile than simple metal detectors: It can find underground utilities, tell the depth of an object, show its exact shape or size, and define its physical makeup as well as its precise angle under the earth. The device has also proven effective in discovering and excavating ruins of historic battlefields, castles, and an ancient abbey in England, says US Radar President Ron LaBarca.

X-RAY SPECS. US Radar's instrument works by sending out pulses that create an electrical echo when they collide with an object. The echo created by moving the radar across the surface of the underground object is used to create a picture, similar to that generated by ultrasound. And because the technology uses different antenna points, it can locate objects through surfaces that can befuddle radar — like concrete.

That's also where Campbell (Calif.)-based Zircon comes in. Having made Stud Sensors since 1980, Zircon is now planning to employ ultrawideband technology in a new product. Called RadarVision, it would enable concrete workers and highway contractors to "see through" solid slabs of concrete. The device would detect steel or other material embedded in up to 18 inches of concrete or similar surfaces. Construction crews need to know what they're drilling into when using diamond-tipped drills because hitting steel instantly destroys the costly tips.

Zircon hopes to have the ultrawideband technology in use by next year. "The only remaining hurdle we have to production is FCC approval," says Zircon Vice-President Chuck Hager, who has provided the device to FCC commissioners for testing on their spectrum analyzers.

Assuming the official test results from all three companies show no harmful effects on the spectrum at large, most industry analysts expect the FCC to give ultrawideband the green light. When this happens, at least 10 other companies are waiting, ready to begin marketing everything from tracking units that provide continuous readings of your child's whereabouts in a crowded amusement park to devices able to pinpoint the location of victims trapped in the rubble of a collapsed building. Broadband may be the hot topic today, but ultrawideband is ready to heat up tomorrow. □

EDITED BY DOUGLAS HARBRECHT

ard L. Brandt

Move Over, Sliced Bread

April 02, 1999

Against his best intentions, Ralph Petroff fell into entrepreneurialism. His father was a Bulgarian engineer who came to the United States at the time of Sputnik to work with rocket scientist Werner von Braun on the Apollo program, then became an entrepreneur. After one of his father's companies went bankrupt, Petroff, his father and two brothers decided to start a company doing pollution monitoring. The family sold the business in 1995 to a Swedish company and decided to take their cash and play the angel investment game from their home in Huntsville, Ala.

That's when they were approached by Larry Fullerton, an iconoclastic engineer who came calling with a company called Time Domain Inc. and claims of having created a revolutionary new technology for wireless communications. Not only could the technology send wireless digital data, it could generate radar that could see through walls and bounce signals off objects to pinpoint their locations. On top of that, Fullerton and Time Domain were fighting with Lawrence Livermore Labs over ownership of the patents to the technology. Was this guy for real? Petroff's engineering family decided he was. In late 1996, the family tossed in $3 million of its own money and helped raise an additional $17 million from angels and MCI WorldCom. Famed Silicon Valley entrepreneur and self-professed "mentor capitalist" Heidi Roizen is on the Time Domain advisory board, and IBM Corp. has signed on as the foundry to manufacture chips based on the technology. The company's technology has already made it into the pages of the New York Times.

We talked to Petroff, who is now the president, CEO and chairman of Time Domain, on March 25.

Upside Today: So how did this company get started?

Petroff: After we sold the family business, I decided I'm never going to work another day in my life at a regular job. I am going to go and have a lot of fun, lose 50 pounds, learn how to speak better French, spend time with the kids, the parents and do some angel investing, because I like business. Right off the bat, who did we run into but a fellow we had known for many years, this remarkable Larry Fullerton character, who had sort of a legendary reputation in a town full of legendary engineers. We had worked with him before, and he had done some great stuff. He was looking for funding and showed us 22 prototypes that he had made. He [could send] video signals from one side of a building to another using only fifty-millionths of a watt of transmitted power. This is going through six, seven, eight, nine, 10 walls. And then he started showing us invisible security fences and domes that could tell you the size and shape of objects it penetrated; and then a radio that transmitted at such low power across so many frequencies that it couldn't be detected, a stealth radio. I felt like the caveman seeing fire for the first time. This was the coolest thing I'd ever seen. That was the good news. The bad news was, he had no money, he had no management team, and he had all kinds of corporate complexities. He also told us about this Livermore outfit trying to claim a branch of the technology that he was working on.

Upside Today: And that branch of the technology is?

Petroff: The pulse radar. You have a problem there, because you can't sue entities that have virtually unlimited financial resources. If it was General Motors, you could bring them to court, but a top-secret weapons lab?

Upside Today: Was Fullerton ever at Lawrence Livermore, or did they just develop it independently?

Petroff: He made a presentation to an audience that included almost a dozen Livermore people. Within several days they started working on a similar kind of thing, trying to come up with this technology. Livermore's credibility has been tremendously undermined [because of this] and it is becoming less of an issue. But for a long time, there were many people who knew about the Fullerton technology, but they were concerned about investing because Livermore might come in and sue them.

Upside Today: How is that dispute being resolved?

Petroff: The House Science Committee [is investigating]. We are all waiting with bated breath to see what they report.

Upside Today: Is the House Science Committee going to make a final decision, or will it just make a recommendation?

Petroff: It's really a Patent Office call. But the process at the Patent Office can take 10 or 15 years. But I think the [House] report is going to describe in great detail exactly what went on, and then make various recommendations for how to prevent this kind of stuff from happening again.

Upside Today: Where did Fullerton develop this technology? Was he doing this independently? Was he at a company or a research lab?

Petroff: Larry was just working on his own. He was listening to a professor talk about radios and antennas, and the professor [said], "You can't do this." And he said, "Wait a minute. I can see a way of doing that." He is a classic American archetype of the brilliant lone inventor. At first we thought, "Gosh, this is too high-risk. We can't put our money in this." But we did our due diligence, and we concluded that he had excellent patent coverage. Three different patent attorneys told us, "If you put the resources into it, you'll beat Livermore." We concluded that this is a fundamental technology. We could make a straight-faced case to ourselves that this had the potential to be one of those transistor/laser/microprocessor kind of once-every-decade-or-two fundamental technologies.

Upside Today: How does the technology work?

Petroff: The signal starts out as a digital pulse. This pulse travels at the speed of light.[It lasts for less than a billionth of a second], so is just six inches long. Then there is dead silence. Then, when the signal is somewhere way down the hall over there, the next pulse pops out. If the next pulse pops out an inch late, it's a one; an inch early, it's a zero. So it's almost like somebody doing Morse Code at the speed of light.

Upside Today: So there is a precise time delay between each pulse, but then if you modify that time delay either forward or backward, then that gives you the zero or one?

Petroff: You got it! But we do something else, too. If you send it out every hundred feet, and if you have 100 users nearby, two of them end up having the same code and would be stepping on each other's signal. So you send it out in a pseudo-random code. The first may be every 62 feet, the next one every 115 feet, and then the next one every 137 feet. That way you can have lots of guys transmitting at the same time in different codes. These signals are very precisely timed, within 5 picoseconds. At the speed of light, 5 picoseconds is one-two-hundredth of a foot, which is one-sixteenth of an inch. That means you can tell how far away from you the other user is (by measuring how long it takes the signal to arrive). You can position objects anywhere to within one-sixteenth of an inch from here to the moon. You know where everything is in relation to each other. That gives you the positioning.

Upside Today: And that's also how the radar works? You can bounce the signals off of objects and see if they're moving?

Petroff: That's exactly right. Plus, regular radio waves will go through walls, but they get all murky and messed up, and they lose definition. But if you're pinging individual pulses through walls, the only thing that happens is the pulses may get a little bit smaller. But they don't lose their definition. So if you're standing on the other side of the wall, you will get an image the same as if you're standing in the room. That also allows you to send telecommunications signals through walls without needing to crank the power up.

Upside Today: What is the electromagnetic spectrum of the pulses that you're sending out?

Petroff: This thing sends out the signal basically across the whole spectrum, with most of the energy between 1[GHz] and 3GHz. This is where the regulatory process gets interesting. Have you heard of FCC Part 15?

Upside Today: No, I haven't.

Petroff: FCC Part 15 covers devices like your portable PC and your pocket calculator--extremely low electromagnetic emissions. Our device, at one-fifty-millionth of a watt, is a Part 15 level. That allows you to cut across other people's spectrum. But the issue that needs to be resolved with the FCC is that Part 15 [only] allows unintentional emissions, like your pocket calculator unintentionally emits. Our device intentionally emits. It's a two-word battle at the FCC, to try and get them to remove that. That's a long process.

Upside Today: I understand the Federal Aviation Administration (FAA) has some concerns.

Petroff: The FAA has ... a concern that, my gosh, if you have proliferation of these devices, could these have a potential for interference?

Upside Today: Yeah, well, the FAA bans laptops during takeoff and landing without any evidence they cause any interference.

Petroff: That's right. They have no testing procedures. Things like hair dryers, blenders, cars and the flashing yellow lights on the tops of all those devices that are running around the airports all give off higher power levels.

Upside Today: How will this be resolved?

Petroff: That's a good question. I think we'll know within the next week or two, because Sen. [John] McCain [R-Ariz.] has become a champion for this technology, because of its public safety and military benefits.

Upside Today: What is the status of the product now?

Petroff: We've successfully fabricated two of these super-cool silicon germanium chips.

Upside Today: Who manufactured the chips for you?

Petroff: IBM. It says a lot for IBM's vision. They're criticized sometimes for being a slow-thinking company, but they saw the potential in silicon germanium and this technology and helped this obscure company create one of the world's first silicon germanium chips.

Upside Today: So far you have made just two?

Petroff: Yes. We wanted to see, will this stuff work? The real magic is in the first two chips. We've got a huge head start. Best of all, these chips are exceeding expected performance, which is a very rare and pleasant surprise. [Petroff picks up a miniature circuit board with a sample chip.] This is one of the test boards here. This is one of the chips.

Upside Today: Are you planning on just licensing patents or selling products?

Petroff: If you can believe this, for just a few million dollars we have made and delivered to the military some of these devices, a dozen of these stealth radios. And we also made Radarvision, our see-through-walls radar for use in counterterrorism, hostage rescue, drug busts, that kind of thing. But we decided that if you came up with something that is as revolutionary as a transistor, you don't just go out and try and build products. You want to make the best possible chip and leave the commercialization to people [who] understand those markets. If we're creating a whole new industry, it'd be nice to get something else other than just chip sales, to get recurring revenue. So we have this core chip set that can do communications, positioning and radar. Then we get partners and go after mass markets, things like ultra-high-speed wireless networks for the house, precision positioning, human tracking, asset tracking, security domes and fences. If we're lucky we become the new global standard for wireless, intelligent connectivity.

Richard L. Brandt is editor in chief of UPSIDE.

Wireless
February 15, 1999 WEEK www.wirelessweek.com

FCC Considers Pulse Radio Request

By Brad Smith

A technology that challenges a basic concept of the wireless industry is gradually nearing commercial deployment for use in a wide range of bandwidth-intensive applications, from location to wireless local area networks to through-wall radar and covert communications.

The technology is variously called ultra-wideband radio, pulse radio or micropower impulse radar.

The FCC currently is considering a request to commercialize the technology, although there are military and niche products that don't need commission approval. One of the companies, Time Domain Corp. of Huntsville, Ala., delivered a prototype communications product for the U.S.Marine Corps.

What is so unusual about UWB radio technology is that it transmits voice and data digitally by using very short bursts of energy-not using the "normal" wave form that most people envision for wireless communications.

Time Domain's UWB technology, based on work by one of the company's founders, Larry Fullerton, "time modulated" so that the data pulses are precisely transmitted in time blocks of trillions of a second and then correlated by a receiver. Because of the precise timing inherent in the technology, it can be used in location and measurement applications.

No assigned frequency is necessary, nor is a power amplifier. The transmissions are so random and low power that they sound like background noise, making them extremely secure. They also are virtually immune from multipath interference.

Time Domain executives Ralph Petroff, president and Larry Fullerton, Chief technology officer, delivered an ultrawide-band radio prototype to the U.S. Marine Corps.

Some UWB technology also was developed at the Lawrence Livermore National Laboratory in California, which focuses on Micropower Impulse Radar. LLNL filed 30 patents on its technology.

LLNL licensed its UWB technology, developed for national security agencies, to several companies for use in such applications as an electronic dipstick in a car engine to detect fluid levels, a "stud finder" for constructions, a warning device for cars to detect objects near a vehicle and to detect faults in highway bridge decking, according to lab spokesman Gordon Yano.

He said the lab also is looking at a land mine detector, which would pick up non-metal mines.

The FCC became interested enough in UWB that it launched its own "notice of inquiry" last fall to consider changing its rules to allow the technology's commercial use on an unlicensed basis under Part 15 of its regulations. The Federal Aviation Administration filed an objection, saying that UWB might interfere with airline communications.

The commission noted that UWB can be used in precise measurement for radar systems as well as in communication if the impulses are properly modulated.

"UWB radio systems typically use extremely narrow pulse modulation or swept frequency modulation that employs a fast sweep over a wide bandwidth," the commission NOI said. "Because of the type of modulation employed, the emission bandwidths of UWB devices generally exceed one gigahertz and may be greater than 10 gigahertz."

Peggy Sammon, senior vice president of Time Domain, said the company hopes to receive an FCC waiver this year allowing it to test a small number of commercial products.

Time Domain has a product named RadarVision that senses motion behind walls, which law enforcement agencies are interested in, Sammon said. The company also is interested in licensing its technology to others, she said, although Time Domain has delivered a prototype squad level communicator to the Marine Corps. W

March/April 1999 Vol.16, No. 2

MD Computing

The Leading Edge in Medical and Healthcare Informatics

TECH TALK

Catching the Wave BREAKTHROUGHS in WIRELESS TECHNOLOGY

JOHN S. GAGE, M.D.

With exciting new technologies like time domain transmission just around the corner; the wireless future of medicine has never been brighter.

It's only five digits long, but it is the stepping off point for enormous changes in medicine : 802.11- the institute of Electrical and Electronics Engineers (IEEE) standard for wireless communication using the 2.4 GHz ISM (Industrial, Scientific, and Medical) band. IEEE 802.11 promises to eliminate many of the cables coming from the backs of our desktop computers by using radio waves to transmit information rather than electrical cabling. Within a few years, this technological breakthrough will permit truly mobile computing at home and in the workplace, allowing doctors and other medical personnel to walk the hospital halls with portable computers, visit bedsides, and log in patient information. This article discusses two additional wireless local area network initiatives built around the 2.4 GHz band and focuses on time-domain modulation- a new technology of such extraordinary intellectual and practical interest that it may soon revolutionize wireless communications, making the current technology obsolete.

Hopping on the Wireless Bandwagon

A desktop computer with a separate scanner, modem, palmtop, fax, keyboard, printer and perhaps a network connection, is a very hairy business: cables everywhere collecting dust and impeding traffic. So-called portables are even worse, because they must be connected and disconnected to all this paraphernalia each time they are used. To get away from this computer-generated spaghetti, Intel, IBM, and several cellular phone makers have developed a standard called "Bluetooth," which replaces cables with radio waves using the 2.4 GHz band. Each device would contain a microchip measuring less than one square centimeter containing everything necessary for short-range (10 meters) wireless communication. As an added, voice communication would be possible using voice recognition and voice commands. Although it is not yet commercially available- and has yet to strike the fancy of Microsoft-Bluetooth would cost about $5 per device. Information can be found at www.bluetooth.com

It seems, though, that a company based in Vancouver, Washington has beaten the heavyweights to the wireless punch. Diamond Multimedia Systems (www.diamondmm.com) is already marketing a wireless local area network for the home and small office, costing somewhat less than $100 per device. It's a network card that permits multiple computers within 150 feet of one another to communicate and share resources, such as Internet access and printing. The technology in Diamond's system was created by a small 1997 start-up called Alation (www.alation.com) that has independently developed another spread-spectrum, frequency-hopping specification in the 2.4 GHz band they call the HomeCast Open Protocol or HOP.

> If John Harrison's clock had cost a million pounds, it would not have realistically solved the problem, because no one would have dredged up the cash to pay for it.

While this new wireless technology is on the verge of becoming standard issue, and extraordinarily interesting technological breakthrough-time-domain transmission-promises an even brighter wireless future. Before getting into this, though, it's important to review a brief history of technological events relevant to the development of radio communication.

For many centuries, mankind has attached great importance to the accurate measurement of time. For example, prior to the invention of modem, nonpendulum clocks, mariners at sea were unable to reliably determine their longitude (think about a pendulum on ship at sea !). Latitude was easy : They knew how far north above the equator they were simply by measuring the angle of the sun over the horizon; but longitude, the east-west dimension, was a much tougher proposition. Thousands of lives were lost because hopelessly lost due to this inability to accurately determine longitude. The need for accurate chronometers was such an intense preoccupation that the British Admiralty offered a large reward to the individual who could perfect a clock that could accurately tell time at sea. As chronicled in Dava Sobel's marvelous book, *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time* (Penguin), it was John Harrison a carpenter and self-taught clock maker, who finally build one in 1759. Harrison won the reward and provided the British Admiralty with the means to navigate safely over the world's oceans.

What the relation between time and longitude, you may ask ? If a mariner sets out from London time, then, by determining noon at a particular position (the moment when the sun highest in the sky), that can be compared with the time in London. If noon at sea occurs at 1 p.m. in London, then the mariner knows that the ship is 1 hour (or 360.24 degrees) west of the home port. But the clock must be accurate. If it gains or loses even a minute or two per day, the calculation quickly become worthless. John Harrison's clocks were accurate to within 1/5th of a second per day and calculated longitude to within a few miles over long voyages. The inventor had paved the way for the development of modern time-measurement techniques that would ultimately lead to extraordinary innovations in radio communications.

More recently, the United States Air Force put 24 Navstar satellites-each the size of a large automobile and weighting about 1,900 pounds-into orbit 11,000 miles above the earth. This took place over a 15-year period from 1978 to 1993 at a cost of more than $12 billion. The global positioning system (GPS) uses atomic clocks aboard these satellites to broadcast a time signal is received from the time it is sent and multiplying the difference by the speed of light, GPS receivers can determine the distance to several satellites, and, using triangulation, determine their own location to within 50 feet or so. Thus, starting with John Harrison, improvements in timekeeping over the past two centuries have led directly to corresponding improvements in out ability to determine exact locations on earth by several orders of magnitude. As we shall see, this made a tremendous advance radio communication possible.

At this point, the inquisitive reader might ask: "Are there atomic clocks in GPS receivers that make them so precise ?" After all, the accuracy of the distance calculation between satellite and earth is dependent on the accuracy of the time the signal is sent and received. Well, the answer is no; it turns out that GPS receivers have cheap quartz clocks that keep their cost to under $100 (surely it would take a remarkable yard sale to find an atomic clock at that price). However, by receiving the signal of a fourth satellite-in addition to the three satellites whose distance from the receiver is being measured through triangulation-the GPS receiver can improve the accuracy of its lowly quartz clock from one second in a thousand years to that of the more sophisticated clocks abroad the satellites.

But the question of cost is a pivotal one and bears directly on the technology that will replace IEEE 802.11. It is not simply important to measure time accurately; it is equally important to measure it cheaply. If John Harrison's clock had cost a million pounds, it would not have realistically solved the problem of measuring longitude, because no navy at that time would have dredged up the cash to pay for it. And, as we have seen above, while IBM and others seek to develop a $5 radio-communication chip for the home computer, Diamond Multimedia Systems has already developed a $100 network card that accomplishes the same thing that they will undoubtedly profit from until the cheaper device comes on line. The only question is, how many home computer users will want to spend an additional $100 for wireless communication ? Put another way, GPS would just be three letters of the alphabet if cheap quartz clocks were not readily- and cheaply-available. Still, it should be noted parenthetically that the GPS "solution" to the problem of inexpensive time measurements is not really inexpensive. Although the cost-effective use of quartz clocks is a bargain, the $12 billion worth of satellites and the additional few billion more dollars for an Air Force base in California devoted to the care and feeding of those satellites is not exactly cheap. Surely, the soon-to-be ubiquitous GPS receiver is the most heavily government-subsidized consumer technology on earth. ("Free-enterprise" and "government-interference" fanatics take note.)

Like the world's oil reserves, rainforests, and wetlands, the spectrum (3KHz to 300 GHz) is a natural resource that mankind is rapidly depleting.

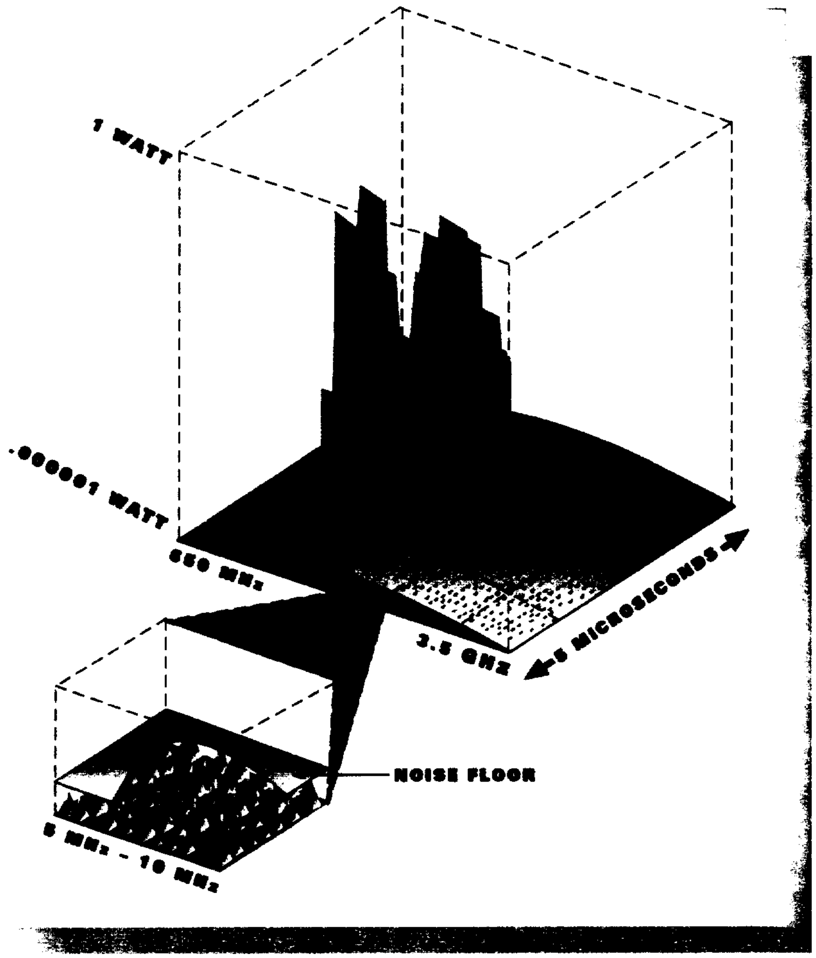
In addition to time measurement, the development of wireless communications has also been driven by the increasing usage of the radio spectrum. Like the world's oil reserves, rainforests, and wetlands, the spectrum (3 KHz to 300 GHz) is a natural resource that mankind is rapidly depleting. New uses, such as IEEE 802.11, are multiplying much faster than our ability to allocate a fixed number of frequencies for them. Part of the reason is that for the past 100 years, which encompasses the entire history of commercial radio, all radio usage has been tied to specific frequencies via either the amplitude modulation of a specific frequency, or frequency modulation around a specific carried frequency to find the radio station we want. The problem facing mankind is that the dial is getting more and more crowded as there are fewer and fewer frequencies available.

Starting in 1987, and inventor named Larry Fullerton, a latter-day John Harrison, looked into using the radio spectrum in a way that was different from traditional frequency tuning. His idea was to use individual radio waves, or "Gaussian monocycles," to carry information. This would effectively transform radio communication into a digital medium, with each monocycle corresponding to a single bit of information. In Fullerton's conception, information would be extracted from a series of individual monocycles by measuring the variation in the time between their transmission; zeroes would correspond to waves that arrive slightly late-a technique he referred to as "time-domain" modulation.

Here, then, is a method of transmitting digital information that is dependent on the accurate measurement of very small periods of time : the intervals between when the individuals waves are supported to arrive and when they actually arrive. How short are these intervals ? Typically they are on the order of a few picoseconds (trillionths of a second). The advantages of employing Gaussian monocycles instead of traditional, frequency-based transmissions are considerable. Let us refer back to IEEE 802.11, Bluetooth, and HOP. All these techniques are based on the ISM 2.4 GHz band and promise bandwidths of 1 or, at best, 10-megabits-per-second. If, however, one is sending Gaussian monocycles at 2.4 GHz, then the theoretical limit of the speed of transmission is on the order of a million times greater. Even if these theoretical limits are not achieved, this method still allows for the transmission of many thousands of times more information i a particular time period than traditional frequency techniques.

Suppose, on the other hand, that instead of using the 2.4 GHz band, we were to use a lower frequency for our Gaussian monocycles. As long as we didn't lower the frequency by many orders of magnitude, we would still greatly increase our bandwidth over traditional transmission frequencies; however, by lowering the frequency just a little, we could greatly improve the ability of the transmission to penetrate solid objects, such as walls and other barriers found in most buildings. Hence, while maintaining greatly increased bandwidth, we are at the same time using time-domain transmissions to tremendously increase the range of broadcasts in the office and home environments.

So is it possible to use lower frequencies than 2.4 GHz without requiring each user of a time-domain device to obtain a license from the FCC ? Unlicensed operation is, after all, the great attraction of the 2.4 GHz band. To answer this question, one must look at the exact nature of the Gaussian monocycle. In essence, it is the radio frequency equivalent of the acoustic "click-the shortest possible sound. One might produce it by taking a pure frequency tone, middle C for example, and progressively shortening its duration. As this happened, however, one would notice that



Time-domain transmission could revolutionize the field of wireless communications. As shown here, conventional signals transmitted in the frequency domain are highly "visible" electronically because all the power is packed into a narrow bandwidth. However, time-domain modulation transmits millions of unstructurred coded monocycles (cyclets) per second across an ultrawide band whose emissions are industringuable from noise- a virtually undetectable communications link.

the frequency of the sound, instead of remaining pure, would start to "spread" over adjacent frequencies until, at the limit, it transmitted energy over nearly all the audible frequencies. Clicks contain all those frequencies. In the case of the Gaussian monocycle, even though one may transmit them at 2.4 GHz, energy will be radiated over several adjacent gigahertz of radio spectrum due to the short, click-like, nature of the monocycles. At first, this may seem like a drawback; and, in fact, the FCC is currently investigating exactly how to treat time-domain transmission. But because the power of the transmission is spread over several gigahertz of radio spectrum, at any specific frequency it is indistinguishable from background noise, making it exceedingly difficult to detect, intercept, or interfere with. Licensing such transmissions would be senseless because no one would be able to detect them or experience interference from them.

A Wireless Future

Time-domain technology is being developed by (Surprise !) a company called Time Domain, Inc. (www.time-domain.com). The principle stumbling block to commercializing it, aside from the bureaucratic wrangling of the FCC, is developing a cheap, integrated circuit capable of measuring the extraordinary short time intervals involved. Time Domain is using IBM's Silicon Germanium lab facilities to create the first prototype of such a circuit.

As this technology matures, we can look forward to a wireless world have now opened the door to medical techniques that are currently unimaginable-but which, no doubt, will save lives as well. **MD** Computing

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